REPORTS

GEOLOGICAL FEATURES AFFECTING THE HYDROLOGICAL CHARACTERISTICS OF THE PARK RANGE EXPERIMENTAL AREA

by
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Prepared for the
Rocky Mountain Forest and Range Experiment Station

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EXPERIMENT STATION

INTRODUCTION

The objective of this report is to describe the geology of the Park Range Experimental Area being used for a controlled test of weather modification as part of the Atmospheric Water Resources Program of the Bureau of Reclamation. The Rocky Mountain Forest and Range Experiment Station is studying the influence of snow pack amount and distribution upon streamflow under contract with the Bureau of Reclamation. The latter phase of the USBR program includes detailed examinations and study of three tributaries of Soda Creek, Fish Creek, and Walton Creek. Water yield is the major factor being studied.

The geology of the three test watersheds on Soda Creek, Fish Creek and Walton Creek was studied more carefully than was the remainder of the target area for the cloud seeding work. Particular emphasis was given to geologic features that could influence water measurement at the three weir locations for the three watersheds.

Field work was conducted in the summer and fall of 1967. Assistance given me during the work by George S. Snyder of the U. S. Geological Survey is gratefully acknowledged. Mr. Snyder mapped the geology of an area north of Fish Creek during intermittent periods of time prior to the summer of 1967. Others who helped me during the field work include several men in the Steamboat Springs offices

of Bollay, Associates, Inc. and the U. S. Forest Service and B. H. Wilford, who was studying forest conditions during the summer of 1967 in the same areas for the Rocky Mountain Forest and Range Experiment Station.

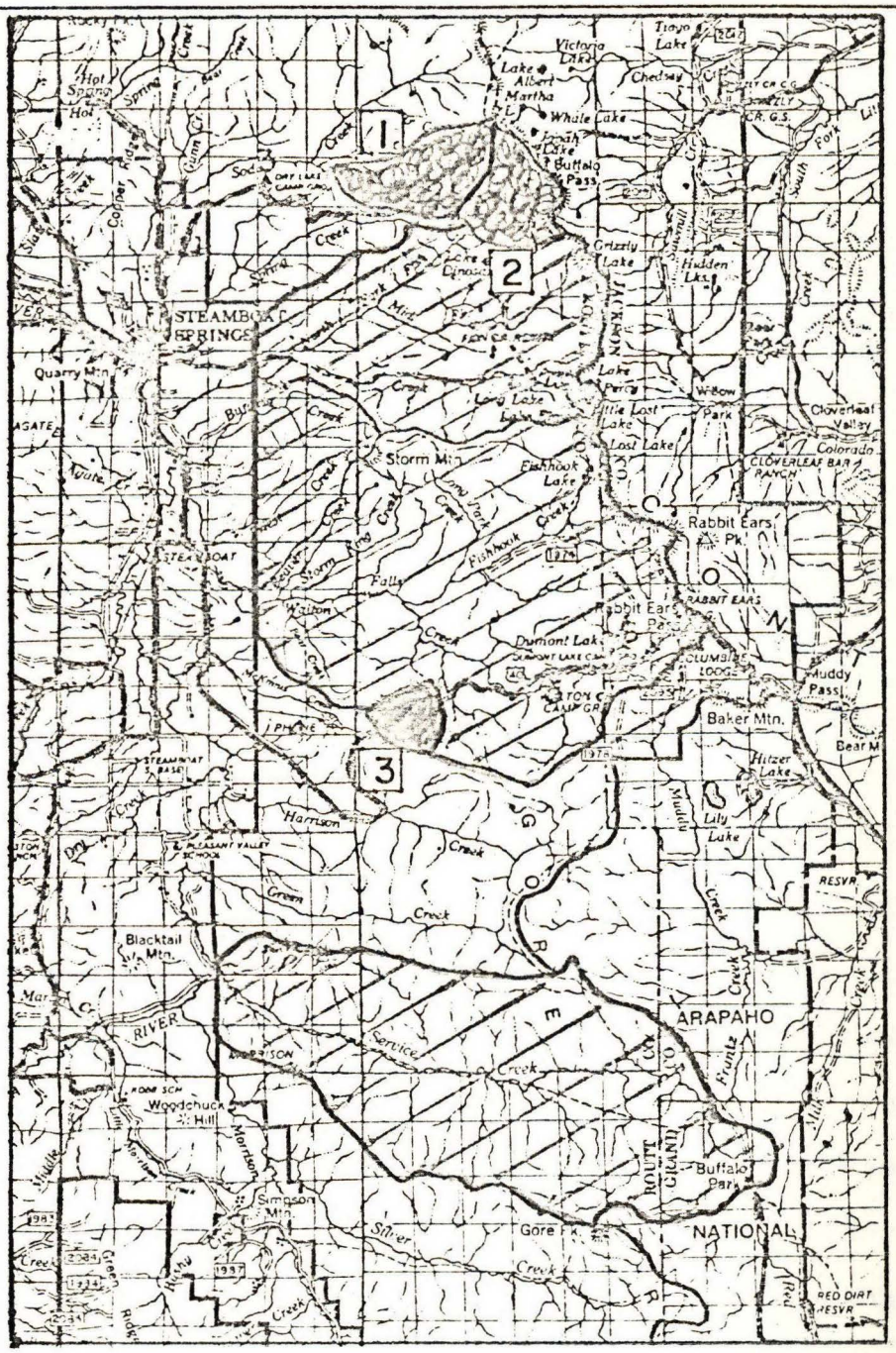
The assistance of Marvin D. Hoover and Charles Leaf of the Rocky Mountain Forest and Range Experiment Station is also gratefully acknowledged.

GENERAL GEOLOGY

The test area is located in the Park Range, which is a north-south trending mountain range in northwestern Colorado. Part of the area is also on the west end of the Rabbit Ears Range, which separates the areas of North Park and Middle Park in Colorado. Rabbit Ears Pass and Buffalo Pass are also in the test area. See Figure 1.

In the Park Range test area the dominant bedrock is granite and interlayered schists, gneisses, amphibolites and metasediments. Basalt and related igneous rocks are also found throughout the southern part of the area as isolated patches, ridges and peaks, such as Rabbit Ears Peak. The various rock types are described and defined in more detail as follows:

Granite is an igneous plutonic rock which contains 10-30% quartz, ~~50~~ 40-60 ~~90~~% potash feldspar, with generally less than 10% of dark-colored accessory minerals, such as biotite and hornblende. It is normally equigranular (without layering). The granite in the vicinity of Summit



Legend

Test Areas

1 --- Soda Creek

2 --- Fish Creek

3 --- Walton Creek

PARK RANGE EXPERIMENTAL AREA

FIG. 1

Reference Map: Routt National Forest, U.S.D.A., Forest Service 1958

Lake is about 1.7 billion years old.[1] Bench mark 10088, which is on the north side of the Buffalo Pass road about 1 3/4 miles west of Summit Lake, is located on an outcrop of granite.

Schist is a medium or coarse grained metamorphic rock with subparallel orientation of the micaceous minerals which dominate its composition. The dark-colored layered rock outcrops on the microwave tower hill south of Summit Lake are good examples of a biotite schist. Biotite schists are somewhat more susceptible to weathering than, for example, granites. A mica-rich residue or mantle is commonly found as a weathering product on the outcrops of biotite schist. Outcrops of a weathered or partially decomposed biotite schist bedrock are especially noticeable in some of the deep cuts along the steep grade section of Highway 40 rising out of the Yampa Valley south of Steamboat Springs, Colorado. In cuts of freshly exposed bedrock, the initial appearance of biotite schist and amphibolite (as described next) is similar. One helpful (and rather obvious) diagnostic feature of a biotite schist is that the weathering product or residue is rich in biotite flakes which sparkle in the sunshine.

Amphibolite is a crystalloblastic (crystalline metamorphic) rock consisting mainly of amphibole and plagioclase. The two minerals must occur in approximately equal

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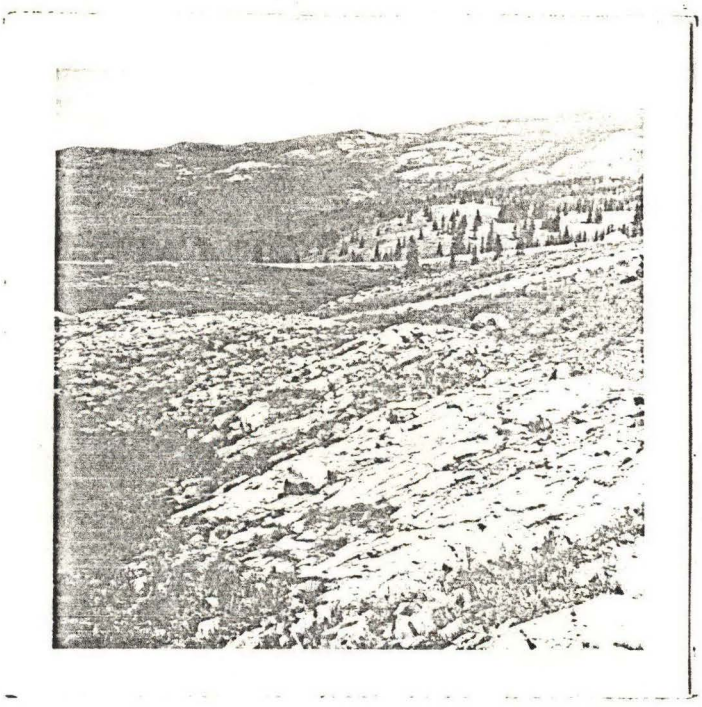
[1] Verbal communication with G. L. Snyder of the U. S. Geological Survey.

amounts and at least 40 percent of each mineral, plagioclase and hornblende. If the content varies from these criteria, the rock is called either plagioclase-hornblende gneiss or hornblende-plagioclase gneiss. Good outcrops of amphibolite are found on the north side of Soda Creek near the confluence of the north and south forks of Soda Creek and also on the microwave tower hill south of Summit Lake. Amphibolite is also present in some of the cuts along Highway 40 south of Steamboat Springs.

Gneiss is a coarse-grained rock in which bands, rich in granular materials, alternate with bands in which schistose minerals predominate. When examined in thin section, a rock containing less 30% micaceous minerals is considered a gneiss. The micaceous minerals must occur in discrete bands and patches or as individual grains. Good outcrops of biotite gneiss are found along an abandoned section of the Buffalo Pass Road north of Buffalo Mountain and at the extreme head end of Spring Creek. See photograph 1.

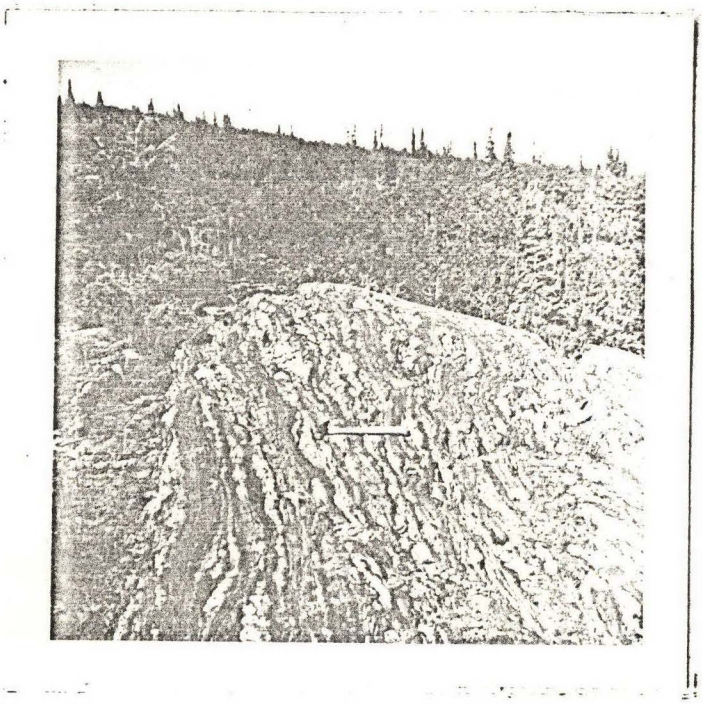
Metasediment refers to a well foliated metamorphic rock, such as gneisses, schists, quartzites and amphibolites, which have been formed by metamorphism of sedimentary rocks. Some metamorphosed volcanic rocks may also be included in a metasediment. Excellent exposures of metasediments are found on the ridge above and to the southeast of Dry Lake campground and also in the canyon above the Soda Creek weir site. In the Soda Creek watershed, the metasediment commonly



Photograph 1 -- View looking north into Soda Creek watershed. Buffalo Pass Road in background. Abandoned section of the pass road in the foreground. Reference elevation is 9687 as shown on the Buffalo Pass quadrangle map.

exhibits white quartz dikes which are alined parallel to the bedding. See photographs 2 and 3 for views of the metasediment and the white quartz dikes.

Basalt refers to an extrusive volcanic flow material which is microcrystalline. It is dark colored, composed of mainly a dark mineral, such as hornblende, pyroxene, etc., and calcic plagioclase. The quartz content is usually less than 10%. The structure of the basalt flow material varies from a dense fine-grained black rock to an extremely weathering-susceptible rock when found in the foam-like scoriaceous form. In some areas, such as on



Photograph 2 -- View of metasediment bedrock exposed on the ridge 0.1 miles southeast of the Dry Lake campground.

Photograph 3 -- View of metasediment bedrock with white quartz dikes north of Buffalo Pass road near the 9687 road elevation as shown on the Buffalo Pass quadrangle map.

Rabbit Ears Peak, layers of rock with unusually large globs of quartz in the basaltic material are found. In the latter case, the rock is called a dacite porphyry.

From a hydrological viewpoint, the aforementioned rock types are essentially impermeable, except where altered by faulting, fracturing, or weathering. The run-off characteristics of the watersheds are also modified in part by mantling deposits, such as glacial moraine material. Thus, the geologic history of the area is of utmost importance because it is the secondary modifications of the bedrock that have produced the individualized hydrological characteristics of each watershed.

GEOLOGICAL HISTORY

In considering the geological history of the area, the oldest influences are the faulting and fracturing which have been accumulating in the bedrock since pre-Cambrian time. In the north end of the test area, the granites and meta-sediments are intensely fractured and intermittently faulted.[2] However, the fractures and fault zones are relatively tight. Thus, no apparent or at least seemingly significant storage capacity for ground water has been created by the fracturing or faulting of the bedrock. In the south end of the study area in the Service Creek area, the effects of fracturing and faulting, if present, are masked by an apparently deep

[2]Additional details of the fracturing and faulting are discussed later in this report under the discussions for each watershed.

weathered bedrock. The latter observation, however, is based on an aerial reconnaissance only as no on-ground observations were made in the Service Creek watershed.

In regard to the depth of weathering, the depth of in-place weathered bedrock increases from north to south in the test area. The remaining depth of weathering is obviously intimately related to the erosional history of the area. Hence in the north end of the area in the vicinity of Soda Creek, glacial activity and subsequent stream action has produced relatively fresh unweathered bedrock. The weathered zones, if any were ever present, have been largely removed by erosion. In the area of the Walton Creek watershed, a deeper weathered zone is present in the metasediment bedrock (in areas where it may be seen) but the bedrock is generally covered by basaltic flows or by glacial debris.

The relationship between weathered and relatively unweathered metasediment bedrock is very noticeable in the deep cut sections of Highway 40 south of Steamboat Springs. On the lower end of the road the bedrock is weathered but not intensely, but in the cuts near the top of the steep grade weathering is noticeably deeper than on the low end of the road. In fact, the metasediment in the road cut on the west end of the Walton Creek watershed is highly weathered and altered to a depth in excess of 50 feet. The depth of weathering is intimately related to the environment existing during Tertiary to present time. According

to Tweto, et al. (1957)[3], the topography in the area that is presently the Park Range area, was similar to the present topography, but the stream system may have been oriented differently than at present. During middle to late Tertiary time, the entire area of northwestern Colorado and southern Wyoming was gradually covered or buried - possibly to a highland elevation of as much as 11,000 feet - with debris resulting from mountain building accompanied by volcanic activity.

At maximum development, the high relatively flat surface of the North Park formation ~~(also called Coalmont formation and Middle Park formation~~) provided an unconsolidated surface on which the ancestral rivers of the present river systems meandered unimpeded across buried basins and mountain peaks alike. There is some indication that at this time of maximum fill in North Park that the drainage divide could have been much farther east than at present. This could explain the rounded mature topography that slopes to the west in the Walton Creek drainage area.

With the termination of Miocene vulcanism, the present drainage systems of the North Platte, Yampa, and Colorado rivers began down-cutting and removing sediments. In some cases, the down-cutting followed weak zones filled by soft Tertiary sediments, but in other cases the rivers were lowered onto and cut new canyons directly across former mountain

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[3]1957 Guidebook, Geology of North and Middle Park Basins, Colorado, Rocky Mountain Association of Geologists.

ranges. The down-cutting probably occurred in stages. High benches cut on the Medicine Bow and Park Ranges at elevations of from 8,800 to 11,000 feet probably represent relatively stable and high levels of basin fill.

In response to the down-cutting of the streams and also possibly due to a regional uplift of the area in late Tertiary time, extensive areas of buried topography were uncovered. Streams of the area deeply incised their channels and great quantities of Miocene and older basin fill were removed by the streams. In addition to the exhumed topography, a large part of this area has been carved into its present form by streams cutting along channels created since late Tertiary time. The many deep and narrow canyons of even the smallest tributaries contrast to the broad rounded forms of the uncovered old topography developed before and possibly also at the time of maximum deposition of the middle Tertiary (Miocene) sediments. For example, consider the terrain in the vicinity of upper Walton Creek compared to the terrain in the upper reaches of Soda Creek.

The preceding story (or hypothesis) is not complete, however, without considering the major effects of glacial activity starting in late Tertiary time and extending up to relatively recent time. Several stages of glaciation have produced typical land forms, such as glacial lakes and deposits of glacial debris. The main momentum of the glacial action was apparently from the area north of

Buffalo Pass extending southward along the divide area into the area west of Rabbit Ears Peak. Major morainal deposits extend from the area north of Rabbit Ears Peak to a south boundary approximately marked by the Rabbit Ears Pass road.

The moraine material ~~near~~ west of Dumont Lake is dominantly granitic which is surprising because of the prevalence of volcanic materials in the area of Rabbit Ears Peak. This seems to indicate that at least part of the volcanic materials, such as the interlayered basalt and dacite porphyry forming Rabbit Ears Peak, were formed after ~~the~~ at least some of the apparent glacial deposits. Some of the basalts, such as those found in the vicinity of Meadows campground, appear to have been flows of very recent origin - perhaps within the past 1000 to 2000 years. In any case, both the glacial and volcanic deposits are of relatively recent origin. From a hydrologic viewpoint, the basalts, especially the scoriaceous (highly vesicular, foam-like) varieties are probably most significant inasmuch as weathering is concerned. The weathering of a scoriaceous basalt into a reddish silty soil proceeds significantly faster than the weathering of the granitic and metasediment materials.

The spectacular drop-off or cliff line alone the east or North Park side of the Park Range from Rabbit Ears Pass to Buffalo Pass is probably mainly related to the faster pace of erosion in the flanking shales found as the bedrock in this area. Another apparent factor relates to the

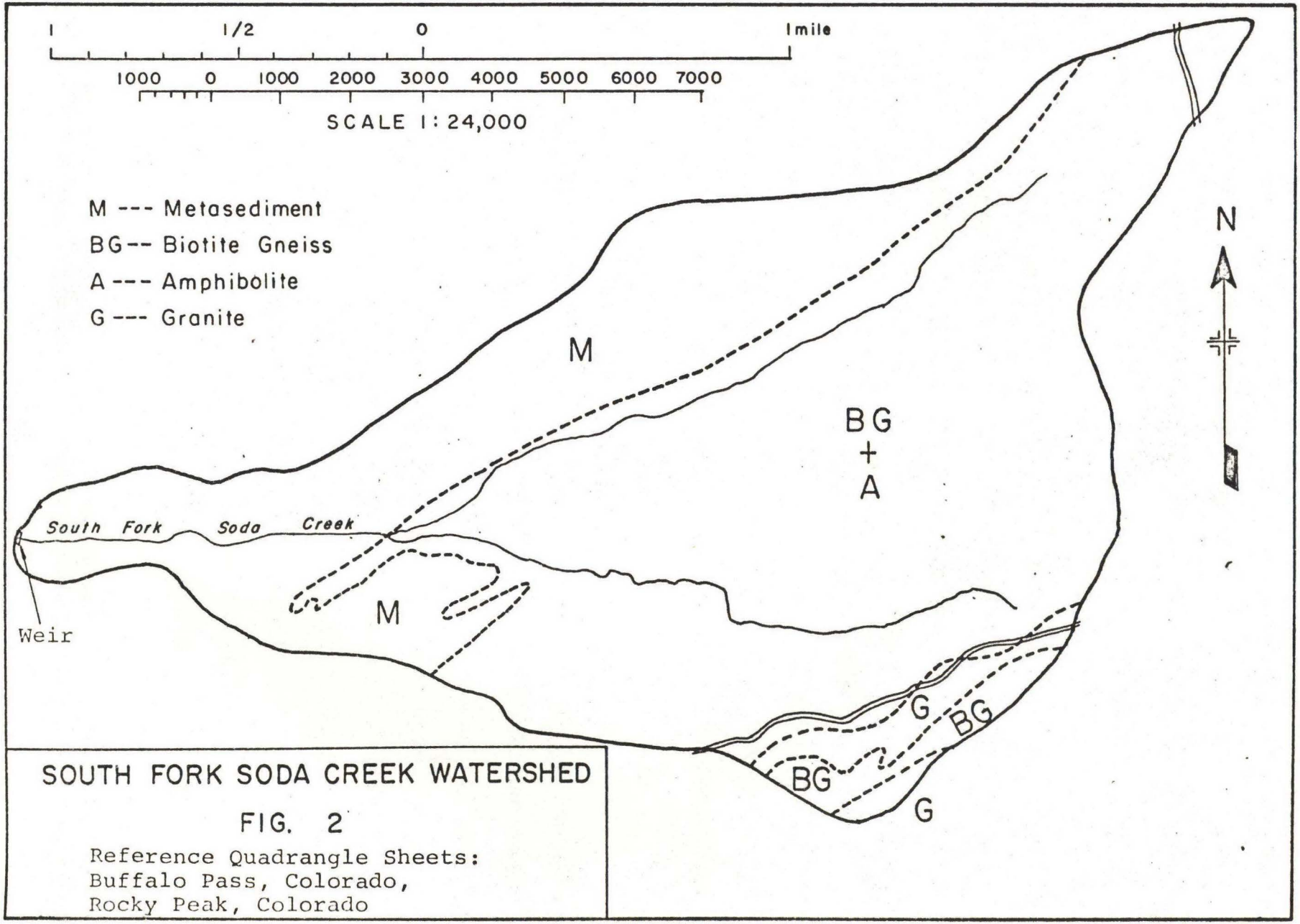
conditions favorable for snow accumulation in the down-wind area east of the Continental Divide and the subsequent cyclic growth and retreat of glaciers in the area during relatively recent time (perhaps during the past 1000 to 2000 years).

SODA CREEK WATERSHED

The Soda Creek watershed ranges in elevation from about 8,300 feet above mean sea level at the weir station to a maximum of about 10,700 on the Continental Divide along the east edge of the watershed. The area of the watershed is about 3.4 square miles.

As may be seen in Figure 2, the bedrock is entirely of pre-Cambrian age. Three main bedrock types are present: metasediment, granite, and biotite gneiss with amphibolite. From a hydrologic viewpoint, all three types could be combined into one mapping unit. All three are hard, relatively unweathered but characterized by a well-developed set of fractures. The fractures, however, are apparently tight, judging from the field examinations. In walking upstream from the weir site, a few small springs were observed but in all cases the springs were small in flow volume. The springs, in all cases, seemed to relate more to talus mantle on steep hillside slopes than to deep-seated and open fractures.

The soil mantle on the bedrock is sparse. This is very evident in the aerial photographs and especially from



SOUTH FORK SODA CREEK WATERSHED

FIG. 2

Reference Quadrangle Sheets:
Buffalo Pass, Colorado,
Rocky Peak, Colorado

an airplane flying over the area. On the relatively flat divide area along the upper edge of the area, the soil mantle is better developed but still relatively shallow - probably in no case deeper than 10 feet, even in the wet muskeg areas.

The sparseness of soil mantle is apparently related to an intense glacial gouging of the high areas and to high intensity run-off and erosion in the lower reaches of Soda Creek. During, and especially during the declining stage of the glacial periods, it seems likely that summer run-off was of high intensity. Thus down-cutting of the streams into the bedrock and removal of loose rock or soil mantle, has been very active in relatively recent geological time.

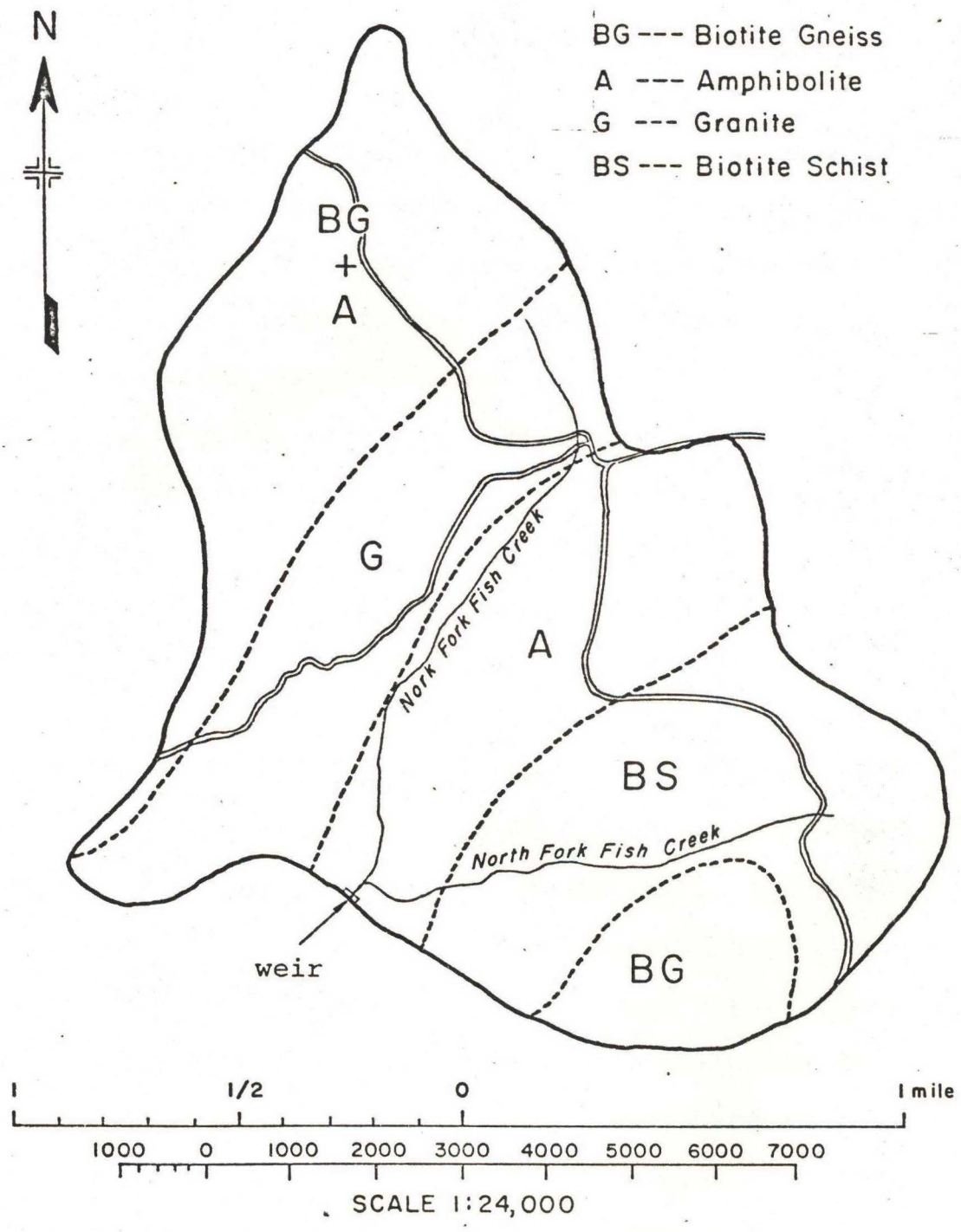
From the foregoing, it is concluded that the ground storage in the Soda Creek watershed is of negligible extent. Limited surface storage, as wet weather small shallow lakes, is found in the relatively flat ridge areas along the upper perimeter parts of the watershed. Since Soda Creek is in a deeply incised canyon section upstream from the gaging site and also since small flows are not lost in flowing through the weir, it would appear that the cut-off wall of the weir is performing satisfactorily and that no significant under-flow of groundwater is going around or under the weir.

NORTH FORK FISH CREEK WATERSHED

The North Fork of Fish Creek watershed ranges in elevation from about 9,800 feet at the weir station to a maximum of about 10,700 feet on the Continental Divide at the northernmost corner of the watershed. The area of the watershed is about 2¼ square miles.

The bedrock in this watershed, as may be seen in Figure 3, is entirely of pre-Cambrian age. The rock types range from granite on the northern side of the area to interlayered biotite schist, biotite gneiss, and amphibolite on the southern side. Here again as in the adjacent Soda Creek area, all of the bedrock types could be considered as one unit from the standpoint of hydrologic characteristics of the watershed.

The conditions of soil mantle, depth of weathering, bedrock fracturing for this watershed are very similar to those found in the Soda Creek watershed; thus, the hydrologic characteristics are similar. The ground water and surface water storage capacity in the North Fork of Fish Creek watershed is seemingly of negligible extent. Since the weir cut-off wall is on bedrock and since small flows will carry through the weir pool without apparent loss, underflow loss at the weir does not seem to be a problem. The stream channel below the weir was walked out but since the stream flow was fairly high and the weather rather wet at the time it would be worthwhile to carefully examine the stream channel for groundwater inflow at a time of minimum



NORTH FORK FISH CREEK WATERSHED

FIG. 3

Reference Quadrangle Sheet:
Buffalo Pass, Colorado

stream flow and after a relatively dry period of time.

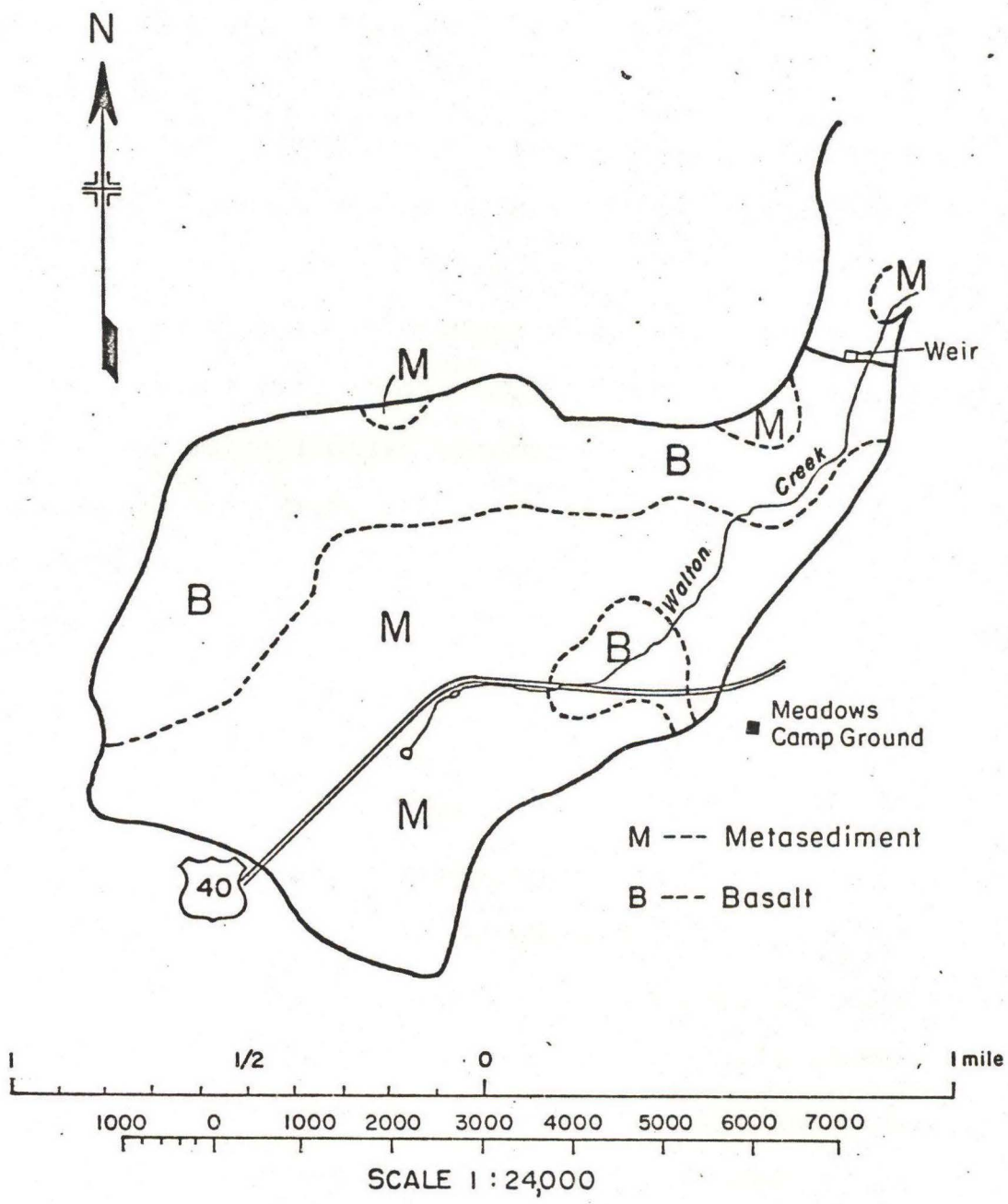
WALTON CREEK WATERSHED

The Walton Creek watershed ranges in elevation from about 9,100 feet at the weir station to a maximum of about 9,728 feet along the north boundary of the watershed. The area of the watershed is about 1.3 square miles.

The bedrock in this watershed, as may be seen in Figure 4, is a mixture of pre-Cambrian age metasediments and late Tertiary age basalt. In contrast to the watershed previously discussed, the Walton Creek watershed has bedrock materials of differing hydrological characteristics.

A fairly deep weathered zone is found in both the metasediment and basalt bedrock materials. Judging from the conditions observed in the road cut at the western edge of the watershed, the depth of weathering in the metasediments may be in excess of 100 feet. The rounded topography of this watershed also indicates a mature, deeply weathered terrain. Glacial action apparently was not localized in this area as it was in the areas to the north. Thus, a significant depth of weathered material remains in the area.

As an additional complicating factor, basalt flows of relatively recent age, are found in the area. The flows occupy both valley bottom and ridge line areas, and range from dense black basalt such as found in the old quarry in the northwest corner of the drainage area, to the



WALTON CREEK WATERSHED

FIG. 4

Reference Quadrangle Sheet:
Storm Mountain, Colorado
Walton Peak, Colorado

foamy-appearing scoriaceous basalt found in the road cut near the Meadows campground. The black basalt is fresh and unweathered except on the surface while the scoriaceous material is intensely weathered to considerable depth (perhaps in excess of 25 feet).

From a groundwater storage viewpoint, the metasediment appears to have very little storage capacity; however, the basalt does store limited amounts of water as evidenced by the springs that frequently mark the contact line between metasediment and the overlying basalt. For example, the latter condition is well illustrated by the springs on both sides of the valley immediately upstream from the weir and also by the springs on the north side of the watershed across from the Meadows campground.

It is concluded, however, that the groundwater storage capacity of the watershed bedrock and mantle is slightly greater than it is for each of the other two watersheds previously discussed. No significant amount of surface storage (small depression, lakes, etc.) exist within the Walton Creek test area, except for several small beaver dams upstream from the Meadows campground. The weir foundation appears to be watertight. Thus, it is doubtful that underflow loss is occurring at this site. One questionable feature remains at the Walton Creek watershed. The basalt on the north perimeter of the watershed was briefly checked for groundwater flow into the beaver pond valley to the

north, but no evidence of groundwater loss was noted. Detailed observations after a prolonged dry period of time would be helpful.

FISH CREEK - WALTON CREEK WATERSHED

The areas of Fish Creek and Walton Creek watersheds between the approximate boundaries of the Buffalo Pass road and the Rabbit Ears road were reconnoitered by foot, car and airplane.

In general, conditions were similar to those previously described for the two northern watersheds of Soda Creek and Fish Creek, except for the following:

a. glacial debris of a granitic nature is evident on the upland divide areas, such as between the Fish Creek reservoir and Fish Hook Lake and from Fish Hook Lake to the vicinity of Dumont Lake;

b. basaltic materials are found on Rabbit Ears Peak and extend westward to the Walton Creek watershed previously discussed.

The bedrock was found to be metasediment throughout most of the area in those areas where it is not mantled by glacial material and volcanic basalt flow material.

From a hydrological viewpoint since this area is many times larger than the test areas on Soda, Fish and Walton creeks, the situation is quite varied as might be expected. In general, however, the three test areas are

representative of the larger area. Limited groundwater storage is found in some areas, especially where the metasediment is mantled by basaltic materials. The glacial materials also have a groundwater storage capacity slightly greater than the metasediment bedrock. The surface and channel storage capacity is slightly greater in some areas, such as in the headwaters areas of Fishhook Creek and Fish Creek, than it is in the test watersheds.

SERVICE CREEK WATERSHED

The Service Creek watershed lies to the south of the Rabbit Ears Pass road. The examinations of this watershed were limited to an aerial reconnaissance on September 23, 1967. A U. S. Forest Service trail traverses the area in an east-west direction, but no automobile or logging roads penetrate the area as yet.

Judging from the State Geology map and the aerial reconnaissance, the area is characterized by several features.

1. The bedrock is a deeply weathered granite of pre-Cambrian age.

2. Glacial deposits are apparently lacking in the area, indicating that it may be that the glacial activity did not extend into the area.

3. The general absence of beaver ponds along the creek seems to indicate a watershed that is characterized by rapid run-off.

4. The groundwater surface storage and bank storage potential of this watershed is limited.

CONCLUSIONS

1. All three weir sites appear to be watertight with no reason to suspect groundwater underflow loss.

2. The groundwater and surface water divides are the same in all three watersheds, with the only questionable area being along the north boundary of Walton Creek where basalt is found.

3. The test watersheds are competent inasmuch as the experimental work is concerned. Nothing was observed during the field studies that would indicate losses from the watershed by groundwater flow. In other words, the input moisture falling on the watersheds should show up at the weir sites.